

Mobile Ad-hoc Networking (MANET) Formulation Considered Harmful

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Novel Methods for Information Sharing in Large-Scale Mobile Ad-hoc Networks
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POSITION

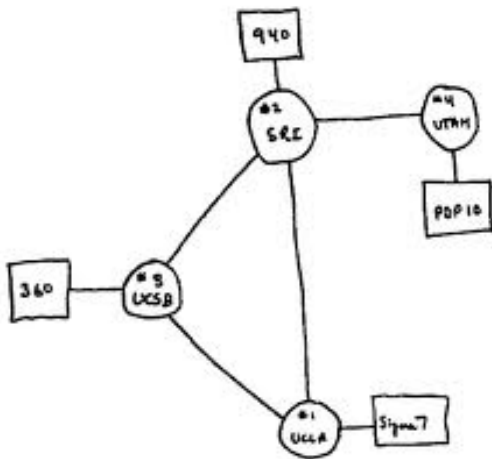
Mobile ad-hoc networking is a narrow problem formulation that—even in its most general form in current practice—is an anachronism mismatched to warfighter needs that has held back progress in tactical networking.

CHALLENGE

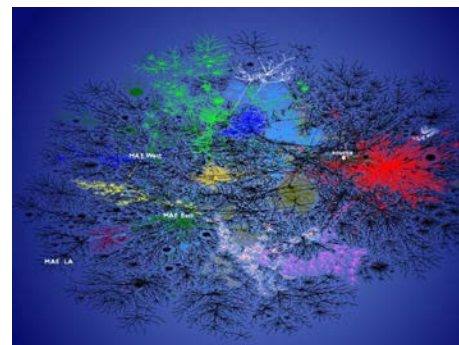
Before this decade is out, connect every warfighter and asset with a high data-rate ($>10\text{Mb/s}$) information service that costs less than \$100 per month per soldier deployed anywhere on or near the planet, and cover as they safely return home!

Let's build: America's Broadband C5ISR Dial-tone service (via Self-* Heterogeneous Information Networks with Global Large Extent

ARPANet c. 1969



Internet c. 2000



Billions of users: **YES**
 Content: **YES**
Heterogeneous: **YES**
Self-Organizing: **NO**

AlohaNet c. 1970



4G Mobile c. 2010



MANET c. 2010

100+ node
MANET
demo

Heterogeneous: **NO**
Self-Organizing: **DO**
YOU COUNT
NEIGHBOR DISCOVERY?

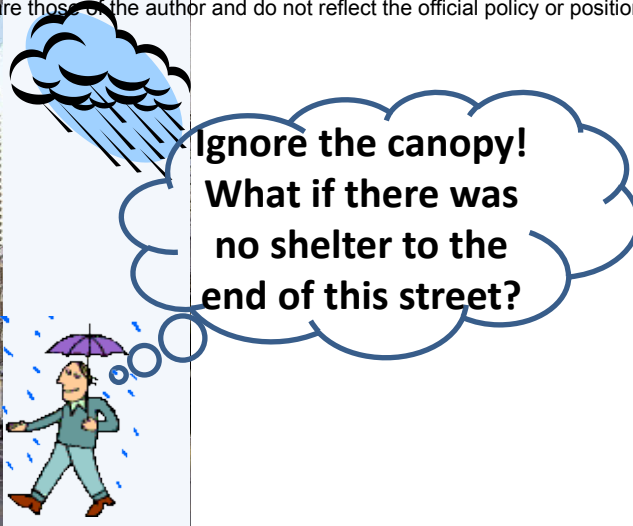


0.3 MIPS, 475W
 32KB Memory
 Paper Tape Storage
 9.6kb/s radio
 1 waveform



4000 MIPS, 0.5W
 2GB Memory
 16GB Storage
 2-54Mb/s radio
 4+ waveforms

MANET Race:
Moore's Law vs.
Inverse Ackermann?



MANET is Narrowly Formulated

- Limited self-organization: ignores infrastructure to own detriment
- Handles similar radios only: multi-hop data walkie-talkie
 - Duplication of effort to insert DSA, MIMO, NC, ... into MANET stovepipe
- Cannot introduce unplanned assets to theater dynamically
- No language to self-describe and self-configure new waveforms
 - How do I share network awareness with non-locality in time and space?
 - Access to teleport supporting waveforms X,Y,Z available five clicks north
 - UAV expected at coordinate C at time T with waveforms X,Y,W
 - What standard should I implement to drop in a hybrid RF-optical link?

Why do least common denominator self-organization in the face of heterogeneity?

Which MANET self-organizes a tactical network of Mobile Hotspots, MAINGATE, WNaN, FOENEX, and F6?

Edouard, the network administrator!

Tactical Network: Show me the MANET



Brigade Combat Team 2013 Network:
5000+ nodes across 18+ network types



Setup takes weeks to months,
but missions change in hours

Army tactical radio inventory	2000	11 types	~365k total
	2010	20 types	~919k total

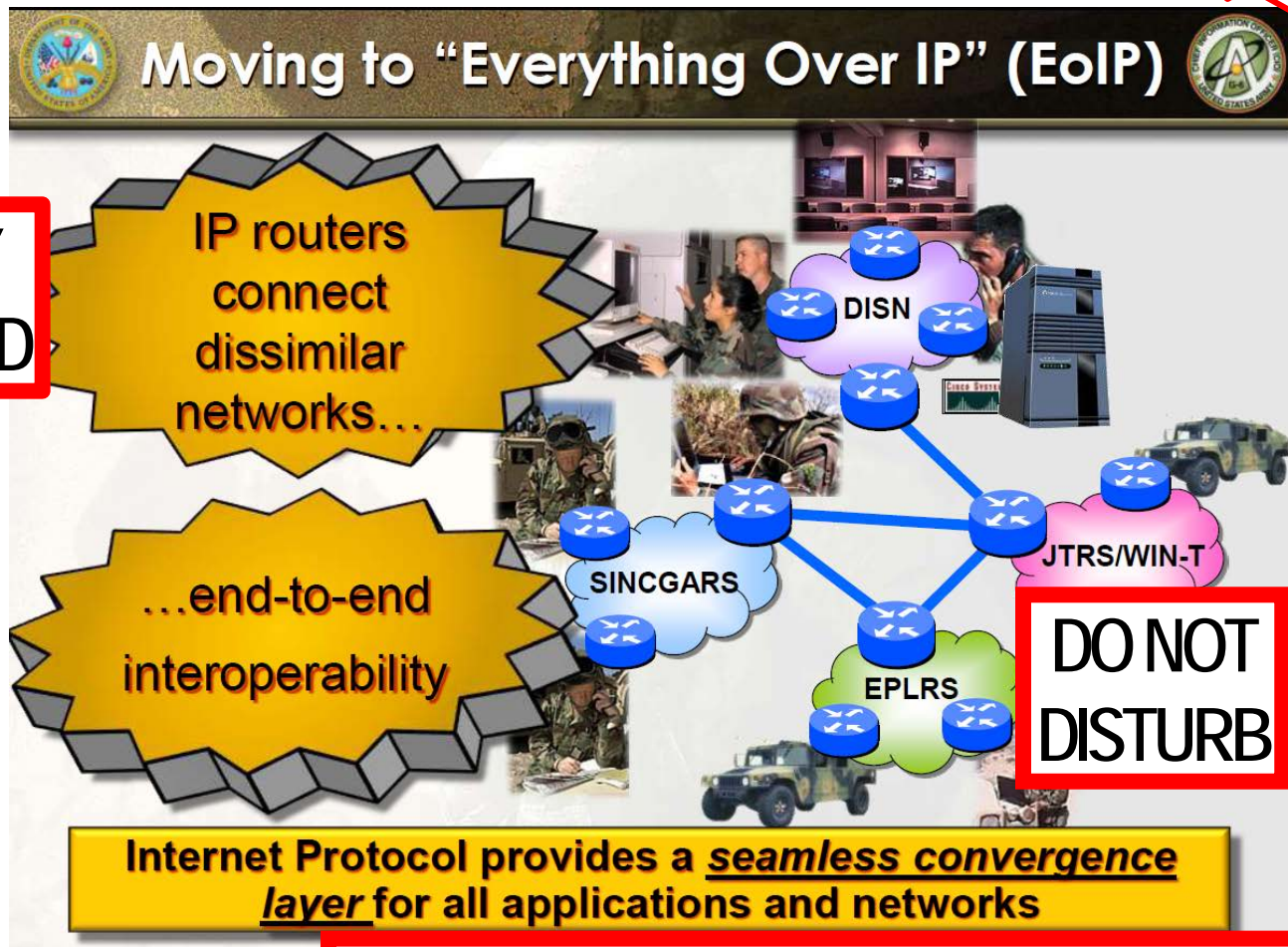
Tactical networks are increasing in heterogeneity and complexity!

"I could go to downtown Tikrit, spend 20 bucks on a cheap Iraqi phone and call my wife in Hawaii in real time. But I can't talk on a secure network with someone halfway across my province without the stars aligning."
—Lt. Col. Donald Brown, USA, commander, 1st Battalion, 27th Infantry Regiment, 2nd Stryker Brigade Combat Team

EoIP Kool-Aid: Are Gateways between MANETs the Solution?

NO!

**MANUALLY
CONFIGURED**

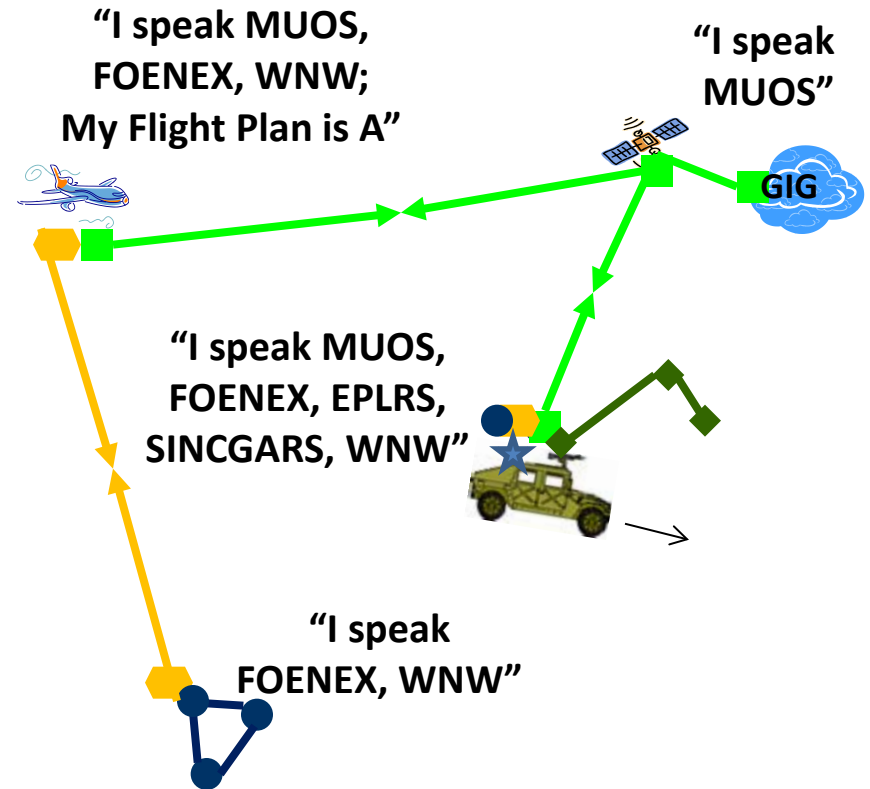
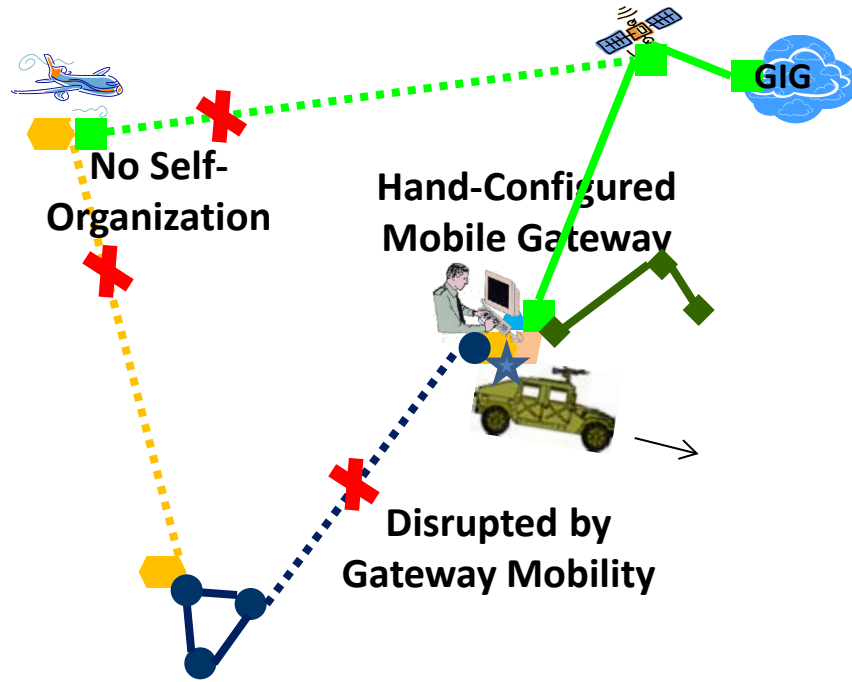


... with a little help from the network admins!

Fragile Gateways: adding new modes increases cost, size, weight, power, and configuration complexity



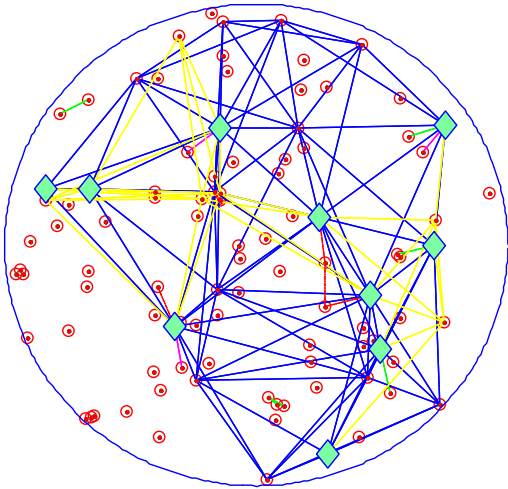
Small Translators: Dissimilar nodes self-organize and communicate via greatest common denominator mode



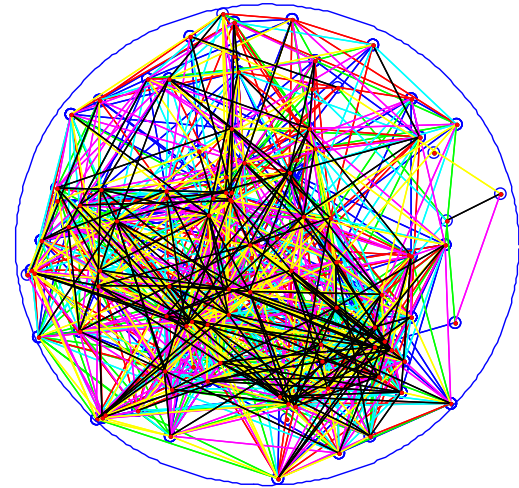
Dissimilar mobile nodes discover each other, self-describe capabilities, self-organize, and communicate using the best available assets without designated gateways!

Gateways vs. Heterogeneous Network

Federation of NETS (10% Gateways)

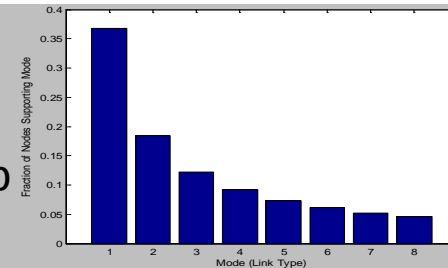


Heterogeneous Nets (4 modes/node)

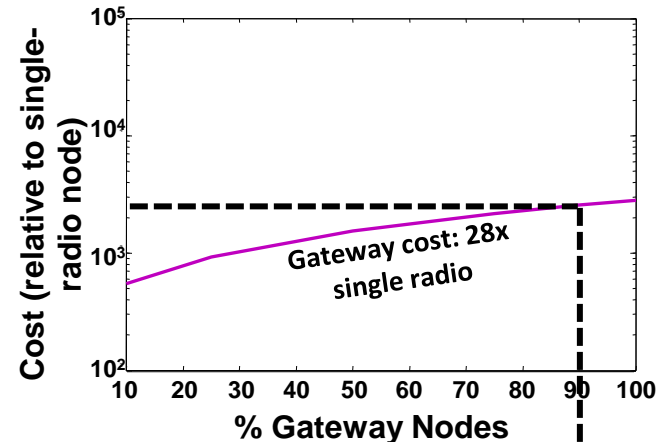
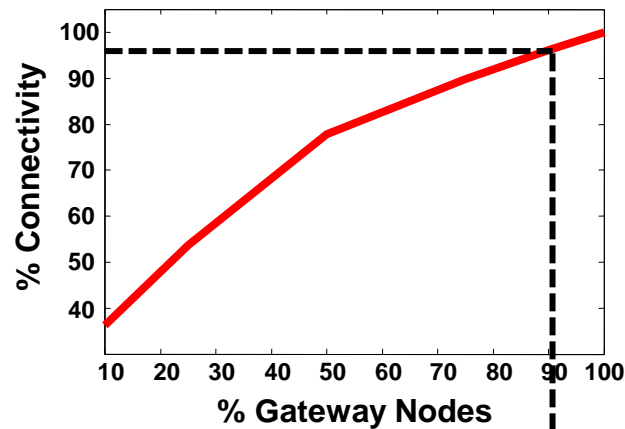
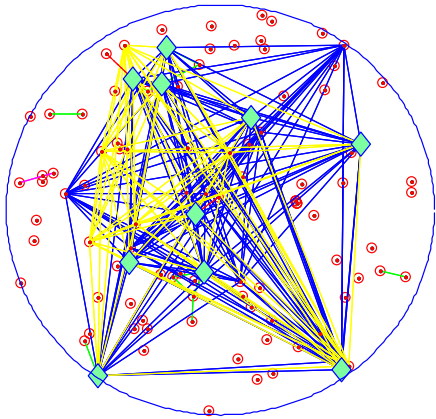


100 nodes
8 modes
25 km dia.

- n : number of nodes
- d : diameter of coverage area
- m_U : distinct modes, popularity **Zipf**-distrib
- three link ranges **250m, 2.5km, 25km**
- m_{HN} : number of modes per heterogeneous node
- γ : fraction of nodes that are gateways
- gateway nodes support all the modes
- c : per-node cost as function of modes is $3 + (m-3)^2$



Limitations of Gateway-Based Solution



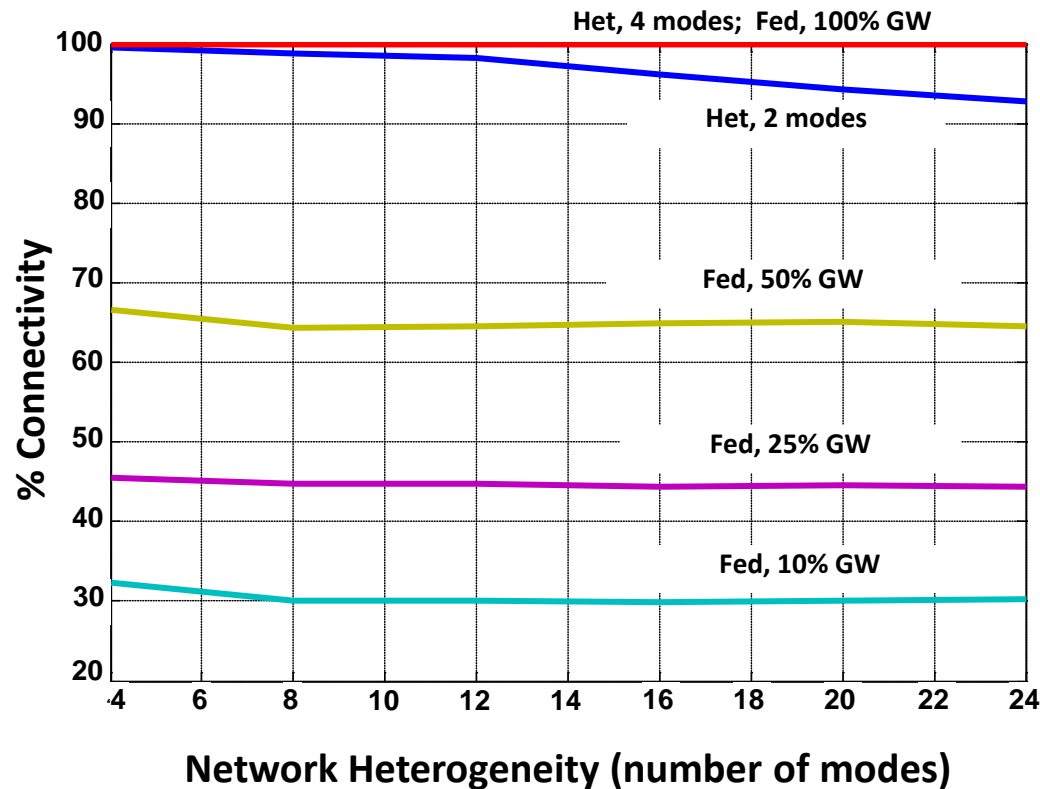
With 10% gateways, ~60% of nodes disconnected

~90% gateways needed to get > 90% connectivity

Cost with 90% gateways: > 25x single-radio network

Gateways: an ineffective and expensive approach to keep network connected

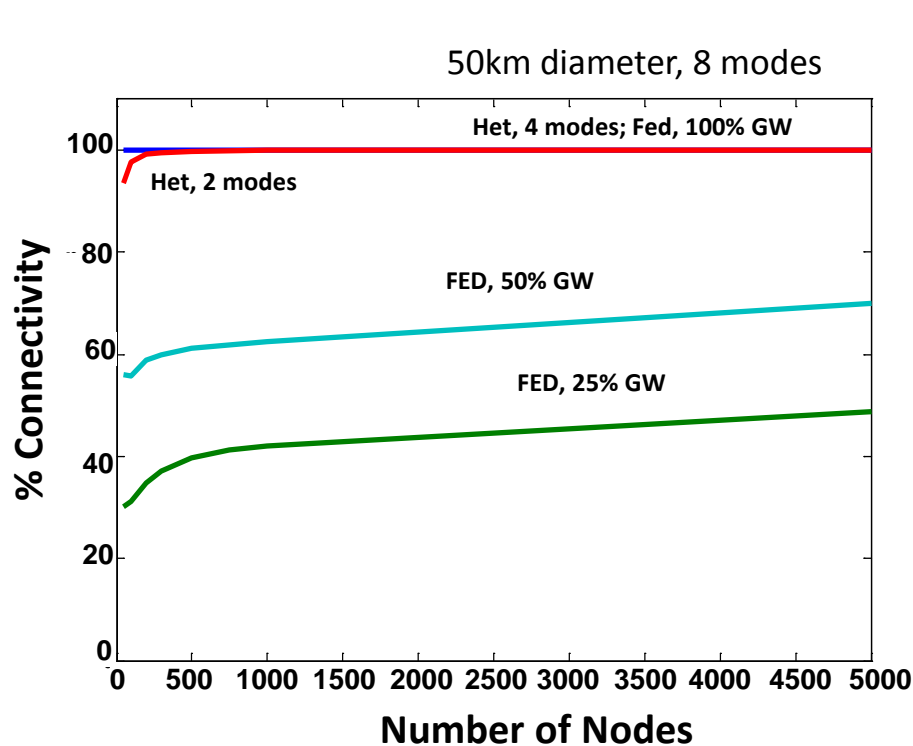
Connectivity



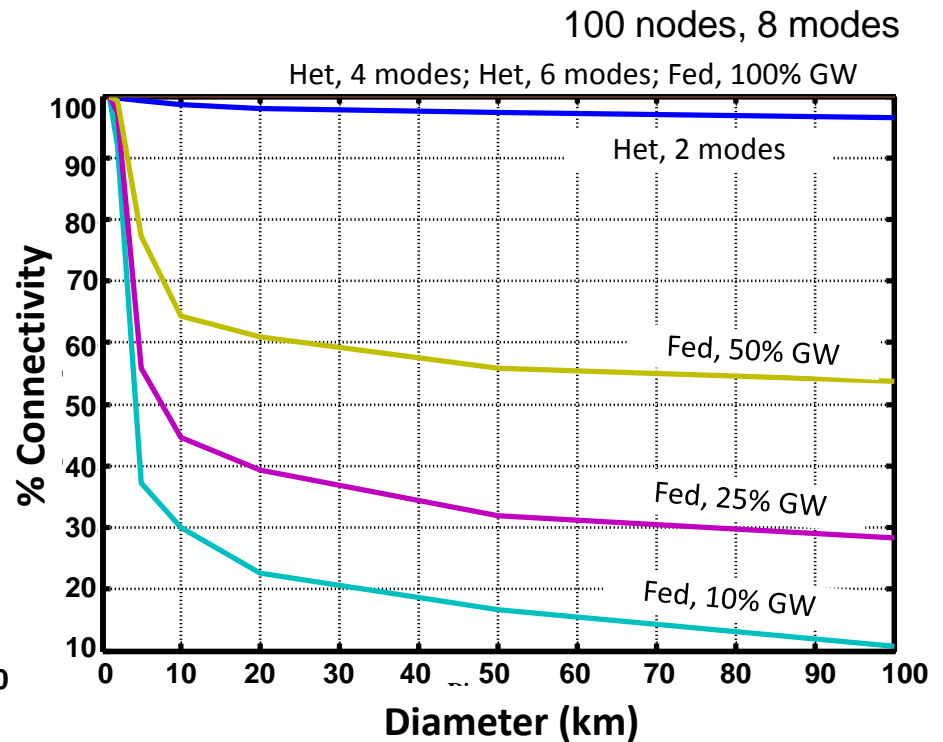
**100% connectivity
at BCT-level heterogeneity**

Heterogeneous self-organization can handle BCT-level heterogeneity

Scalability and Coverage



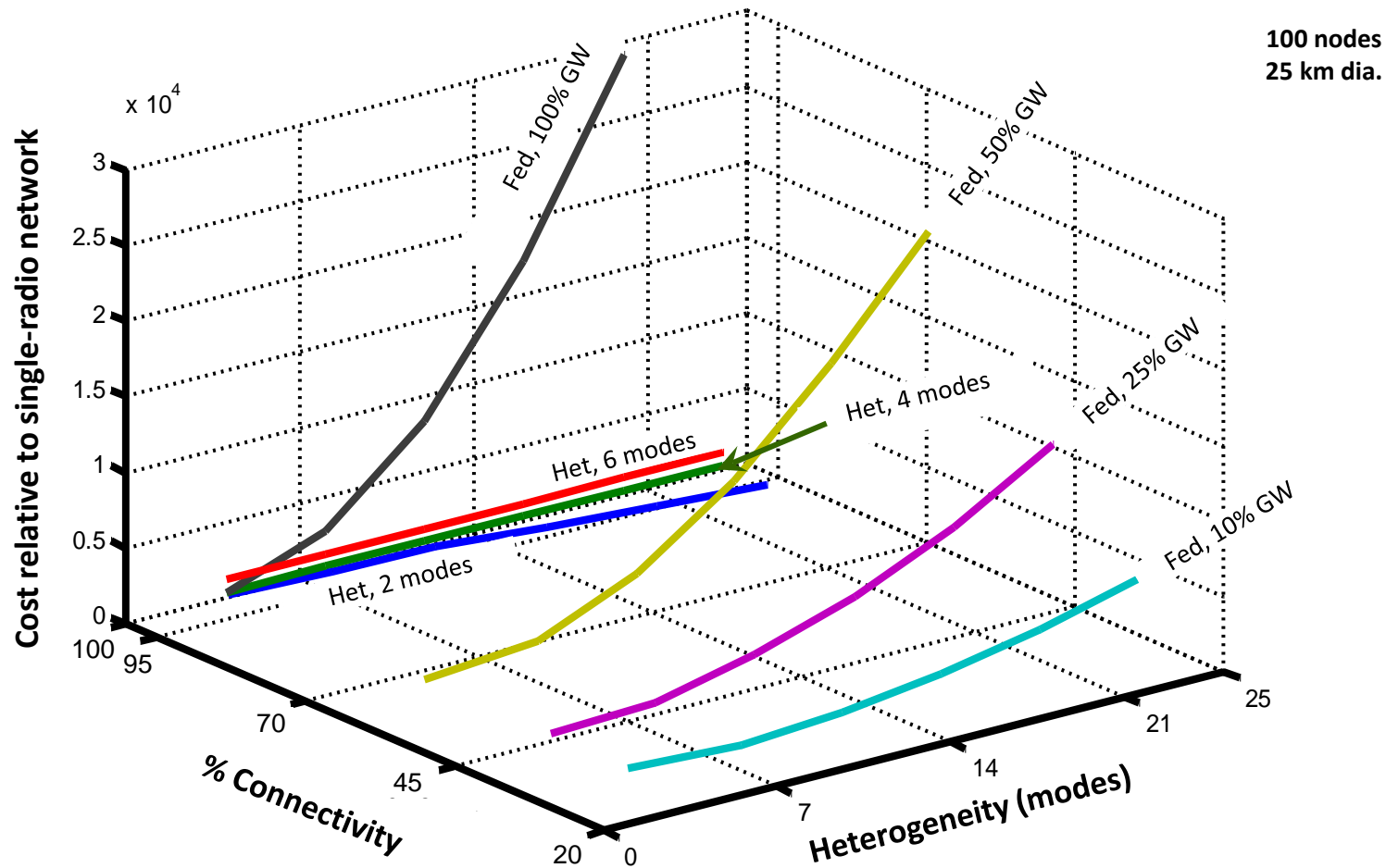
Heterogeneous networks key to scaling



HETNETS covers large areas

Heterogeneous self-organization is key to scaling to big networks and large areas

Cost Benefits



We can connect dissimilar network assets at lower cost than gateways

Networking Grand Challenge

Commanders of the US Joint Forces and Coalitions point to a map and say:

**“Our coalition units X, Y, and Z will deploy at AO Cobra within 6 hours.
O communications layer, cover us!”**

and later add:

“Change of plan, new route. O communications layer, cover us!”

Can we go beyond procuring network equipment, training, and maintenance ...

... to a **reliable repeatable subscription service** that provides affordable high data-rate, secure, **self-deploying** data network to the war-fighter?

Enablers for Grand Challenge

1. Self-* (deploy, describe, discover, configure, manage, defend) multi-modal elements
2. Autonomy interfaces at the network layer for bootstrapping a self-* communication layer
3. Unified topology awareness with non-locality in time and space of heterogeneous assets
4. End-to-end information delivery over space-time path of pair-wise communication modes
5. Survivable access to information, not topology maintenance in a chaotic mobile network
6. Transient network addresses assigned per communication opportunity
7. One-to-many prioritized sync as a fundamental information-centric network primitive
8. Embedded Datalog with queries at line speed
9. Policy-agile black core based on encryption operations on encrypted data
10. Bottom up trust establishment
11. Multi-user detection – cut the Gordian knot of contention
12. Soft-state MAC protocols for time and frequency multiplexing

These are a few of our favorite things!

DARPA-Hard?

- You bet!
- Automated Setup and Teardown of Heterogeneous Mobile Military Networking Infrastructure
 - Disruption-tolerant self-organizing on-command re-deployable
 - Dynamic autonomous airborne, terrestrial and littoral assets
 - Optical, wireless, SATCOM, fixed wireless, and wire-line elements
 - Transient addresses, zero configuration, no prior address allocation
- Secure and Content-Oriented
 - Google, Akamai, and Twitter to go
 - Bottom-up bootstrap of trust with a bump (near-field communication)
 - Data is stored encrypted with ephemeral decryption for use
 - Account for assets at all times, and unaccounted assets zeroize
- Pilot program with 5000 elements spanning area of radius 500km
- \$100 per month per soldier @ 500,000 subscriptions for 2 years

**War-fighters get 4G-quality secure data anywhere on the planet with 6 hours notice.
Information capability outmatches adversary.**



Questions?

Edouard **MANET**

"Toter Torero", Oil on Canvas, 1864-1865
National Gallery of Art, Washington D.C